Chapter 5
Evaluating the Tier II Baseline Ecological Risk Assesment

5.1 Introduction

Proceeding to Tier II is recommended where there is a need to reduce uncertainty from previous investigative phases and to verify the Tier I findings. Proceeding to a Tier II, Tier III, or Tier IV ERA may also be necessary when field studies or bioassays are desired, when Tier I risk is not well-characterized, or when significant questions remain and remediation decisions cannot be adequately addressed (as part of the FS or RD). In Tier II, a shift is made to evaluating population and community level effects. as well as mixtures of chemicals and chronic effects using a biological effects-based approach. The overall objective in Tier II is to produce more accurate, quantitative predictions regarding current and future risks to ecological populations, communities, and ecosystems due to migration of chemicals from the contaminated site.

Tier II may include laboratory or field bioassays and/or more detailed, sophisticated computer models or probabilistic methods. Quantitative biological samples, as well as abiotic samples, as needed, may be collected to document exposure, to assess bioaccumulation potential, or to determine dose-response of the tested species or the selected receptors when exposed to site media. Limited field investigations may be conducted to determine presence of specific receptors or to estimate biodiversity. Tier II may include inexpensive, short-term toxicity tests or bioassays, standard rapid biological field assessment protocols, or focused tissue residue analyses of key receptors or their prey. As needed, semiquantitative sampling of the contaminated and reference sites may be conducted to describe the identity and populations of biota in both areas. If limited fate/transport modeling (e.g., one-dimensional analytical model) is used, site-specific input values for key parameters of the model may be needed.

The biological sampling methods employed in Tier II are simple, short-term, and inexpensive relative to Tiers III and IV. Tier II data, when integrated with data (primarily chemical) collected from the previous phases, should generally be adequate to provide information on the significance of potential or observed ecological effects, the need for remediation/removal actions, and the develop ment of preliminary cleanup goals based on ecological concerns and remedial action objectives.

For specific models and methods that may be employed in a Tier II or higher effort, recent publications from USAERDEC (1994), WERF (1994), and NOAA (1992) can be consulted. Additional resources for ERA sampling and modeling methodologies are provided in Appendix B, Information Sources.

The decision as to which tier to enter depends upon the nature of the site (large versus small site: simple versus complex ecosystems), type(s) of data required (single versus multiple measurement endpoints): and the methods to be employed (desk-top, field, or laboratory). Tie and cost limitations also determine level of effort and tier. Problem reformulation and the identification of data needs should follow guidance provided in the USACE (1995b) *Technical Project Planning* document. If the identified data needs are for short-term, focused, biological sampling and analysis methods, then Tier II activities are appro priate. It is possible, however, that a Tier III or, under unusual circumstances, a Tier IV program may be the more appropriate level of additional activities following Tier I.

In some situations, Tier II procedures such as bioassays may be initiated prior to completion of the Tier I ERA. For example, bioassays or measurements of biological integrity, rather than chemical analyses, may be preferred, or even required under some Federal regulations (40 CFR, Part 227.13, *Federal Regulations on Ocean Dumping of Dredged Sediments;* EPA 1991g) to determine whether a particular abiotic medium (sediment, soil, surface water) is toxic to biota or contains chemicals at concentrations of ecological concern. Exhibit 18 and Figure 5-1 describe such a case and present an example of how the tiered ERA approach may be followed in the assessment of sediment quality and characterization of risk in an aquatic ecosystem. Decisions as to which method to use depend on project objectives, data needs, desired certainty level, and the suitability of each method to meet these needs. A comparison of various methods for assessing sediment quality is shown in Table 5-1.

In addition to methods described in Risk Characterization (Section 4.5). the following tier descriptions mention only a few of the numerous field and laboratory methods that may be employed to better characterize risk or provide a basis for remediation decision-making. The need for measuring additional ecotoxicological endpoints in each tier should be carefully evaluated. When selecting ecotoxicological methodologies, the biological response under consideration and the proposed methodology should satisfy USACE (1995b) Technical Project Planning guidance, as well as consider the following more specific criteria:

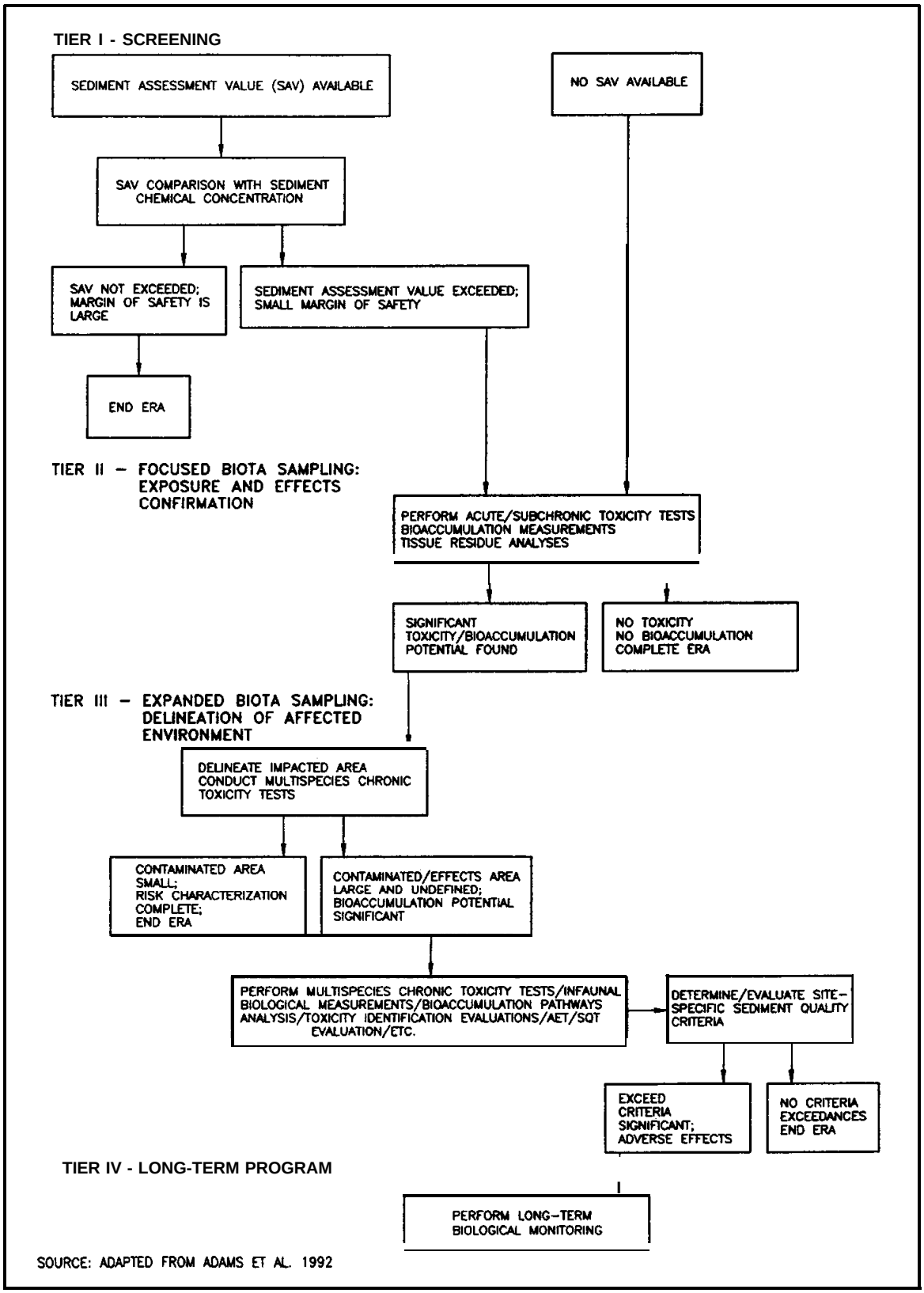

Figure 5-1. Interrelationship of tiers: Sediment quality assessment

Table 5-1
Comparison of Methods for Assessing Sediment Quality (See Exhibit 18)

Sediment Method	Chemical Specific	Site Specific	Integrates Multiple Chemicals	Field Validated	Relative Cost	Method Uncertainty[1]
Equilibrium Partitioning	Yes	No	No	Partially	Low	Moderate
Apparent Effect Threshold	Yes	Yes	Yes	Yes	High	Low/Moderate
Sediment Quality Triad	Yes	Yes	Yes	Yes	High	Low/Moderate
Bulk Sediment Toxicity	No	Yes	Yes	Yes	Low	Low
lnterstitial Water Approach	Yes	Yes	Yes	Partially	Moderate	Moderate
Spiked Sediment Approach	Yes	Yes	No	Partially	Moderate	Moderate
Tissue Residue Approach	Yes	Yes	No	No	High[2]	Unknown
Freshwater Benthic Approach	No	Yes	Yes	Yes	High	Low
Marine Benthic Approach	No	Yes	Yes	Yes	High	Low
Ionic Chemicals	Yes	No	No	No	Low	Unknown
Metals	Yes	No	No	Partially	Low	Moderate/High

[1] The degree of uncertainty for each method is subjective and reflects the authors' opinion and experience. as well as previously reported evaluations
[2] The cost of this approach would be high if both sediments and tissue were analyzed.

Some: Adams, Kimberle. and Barnett 1992.

- The biological response is a well defined, easily identifiable, and documented response to the designated COECs (i.e., methodology and measurement endpoint are appropriate to the exposure pathway).
- Exposure to the COEC is known to cause the biological response in laboratory experiments or experiments with free-ranging organisms.
- Methodology is capable of demonstrating a measurable biological response distinguishable from other environmental factors such as weather or physical site disturbance.
- The biological response can be measured using a published standardized laboratory or field testing methodology.
- The biological response measurement is practical to perform and produces scientifically valid results (e.g., sample size is large enough to have useful statistical power and small Type II error).

The process for deciding which methods to use in each tier should follow Phase II project planning on DQOs, as well as general guidance provided in the following tier planning descriptions. Standardized protocol and detailed descriptions of some of the numerous ecotoxicological investigative methods available are provided in various agency (EPA, ASTM, FDA, USAERDEC, NOAA, WERF) publications (see Appendix B, Information Sources). Tables 5-2 and 5-3 provide an overview of the types of methods that are available and the types of information provided by such methods.

5.2 Problem Formulation

A listing and assessment of the ecological issues and data needs that remain following the Tier I ERA should be conducted The assessment and measurement endpoints used in the Tier I BRA should be reviewed to see if they

Table 5-2
Ecological Risk Assessment Approaches, Techniques, and Endpoints Used to Characterize Potential Risk

Characterization of Potential Risk

Approaches	Techniques	Endpoints*	Information Provided	Information Not Provided
Comparison of Measured and/or Projected Contaminant Concentrations to Ecological Benchmark Levels	Measured Concentrations Projected Concentrations (Quotient Method)	Mortality Reproduction Growth Community Structure AWQC NOELs/LOELs	Yes/No information as to whether impacts are likely: Impacts resulting from direct exposures as well as indirect exposure via food chains Ecologically based cleanup criteria for single contaminants	Quantitative measures of severity of impacts if benchmarks are exceeded Impacts to communities or ecosystems (unless benchmarks specifically account for these)
Estimate of Exposure Potential (No Benchmark)	Measured Concentrations Projected Concentrations Qualitative Evaluation	Mortality Reproduction Growth Community Structure	Types of ecosystems and receptors potentially exposed to contaminants Identification of potential exposure pathways	Likelihood or severity of impacts Areal extent and reversibility of impacts Uncertainty of the characterization.
Estimate of Hazard Potential (Media Toxicity Tests)	Laboratory Toxicity Tests In-Situ Toxicity Tests	Mortality Reproduction Growth Tissue Residue Level	Quantification of likelihood and severity of impacts to populations of test organisms Identification of hazards to site-specific populations Areal extent of impacts (if media tested at sufficient number of locations) Ecologically based cleanup criteria for mixtures of contaminants	Impacts to communities or the ecosystem: Interpretation of test results can be difficult (e.g., basis for the toxic response)
Quantitative Risk Modeling	Fault-Tree Analysis Probabilistic Pathway Analysis Multiple Attribute Ranking (Linear Models)	Reproduction Failure	Specific probabilistic prediction of the likelihood of specific impacts to individual organisms, populations, communities, or the ecosystem Severity and areal extent of impacts Quantification of ecological risks for risk management decisions	Major disadvantage can be cost to implement

Source: EPA 1989k. Ecological Risk Assessment Methods: A Review and Evaluation of Past Practices in the Superfund and RCRA Programs. EPA/600/8-89/043.

* Definition of endpoint in this table is different from the *Framework* (EPA 1992a) definition of endpoint currently in use.

are appropriate and applicable to anticipated remediation decisions. The additional biological/toxicological data requirements should be identified to help identify the appropriate tier and scope of additional investigations. Existing applicable data regarding potentially affected biological communities, environmental fate of COECs, bioconcentration and bioavailability of the COECs, toxicity data, and COEC concentrations in abiotic exposure media should be reviewed and data needs identified. Conclusions of the Tier I ERA that require a reduction in the associated uncertainty levels should be identified.

Once the additional data types that are needed are identified and the appropriate tier confirmed, problem formulation should commence. An initial step in problem formulation may be the development of working hypotheses. Hypothesis development is essential when statistical

Table 5-3
Ecological Risk Assessment Approaches, Techniques, and Endpoints Used to Characterize Actual Risk

Characterization of Actual Risk

Approaches	Techniques	Endpoints*	Information Provided	Information Not Provided
Evaluation of Biotic Community Structure	Quantitative Sampling	Diversity Indices	Identify large, major, and readily apparent impacts	Subtle impacts Impacts to populations Severity of impacts
	Qualitative Surveys Aerial Photography	Description of Community	Areal extent of impacts Identify small subtle impacts Potential exposure pathways and contaminant effects	Minor impacts Likelihood, severity or ecological significance of minor impacts
Evaluation of Individual Morphology or Physiology	Field Sampling Histopathology Necropsy Records of Mortality	Tissue Residue Levels Disease/ Abnormalities Reproduction	Direct evidence of injury to individuals Areal extent of major impacts to individuals	Impacts to populations, communities, or the ecosystem
	Detailed Field Studies	Tissue Residue Levels Disease/ Abnormalities Reproduction	Quantification of small, subtle impacts to individuals or populations	Impacts to communities or the ecosystem
Qualitative Surveys Aerial Photography				

Source: EPA 1989k. Ecological Risk Assessment Methods: A Review and Evaluation of Past Practices in the Superfund and RCRA Programs. EPA/600/8-89/043.

*Definition of endpoint in this table is different from the *Framework* (EPA 1992a) definition of endpoint currently in use.

comparisons are anticipated (e.g., comparisons of onsite with offsite biotic populations).

Next, appropriate sampling and analysis methods should be identified and detailed Tier II work plans developed. The biological sampling methods employed should be simple, short-term, and inexpensive relative to Tiers III and IV. Because most of the sampling conducted within Tier II is short-term, seasonality of the species, population, or community to be sampled should be carefully considered, so that representative biotic samples can be collected. For example, if an assessment endpoint concerns adverse effects in nesting birds, then bird surveys should be conducted in the summer; if, however, the assessment endpoint concerns migratory bids, more appropriate seasons for surveys are spring and fall. Also, locations of biological sampling should be chosen in view of the previous sampling of exposure point media and any anticipated Tier II abiotic sampling and chemical analysis.

Tier II may include descriptive sampling and measurement of ecological attributes such as tissue residue levels or biological diversity in the contaminated area compared with a nearby reference area. Ecological attributes that can be adversely affected by contaminants are numerous (see Table 54). Selection of which attributes to measure should be well documented and based on USACE (1995b) Technical Project Planning guidance. Comparison of ecological attribute measurements made at the reference and contaminated sites can provide a qualitative measure of the ecological similarity between the two sites. Interpretation of the significance of differences in measurements between contaminated and reference sites is not always straightforward, especially where there are a large number of species present and the analyses become quite complex. The detection of differences between contaminated and reference communities does not necessarily indicate that contaminants are exerting biological effects.

Table 5-4
Ecological Atributes

Distribution
Sex-specific
Breeding-related
Age-specific
Food-supply related
Migration-staging related
Molting-related
Seasonal migration
Vertical migration

Population Characteristics
Population size
Uniqueness of population
Proportion of population likely to be affected
Location of recolonization populations
Population dispersion efficiency and mechanisms

Life History Characteristics
Fecundity
Number of offspring
Number of reproductions
Generation time
Mortality rate and pattern
Biochemistry and enzyme systems
Behavioral characteristics
  Dormancy
    Hibernation
    Estivation
  Physical movement
    Dispersal
    Migration
    Refuging
    Dispersion
  Selective behavior (e.g., feeding, habitat selection)

Habitat-Related Characteristics
Habitat specificity
Habitat availability
Extent of habitat
Potential for habitat destruction
  Direct vegetation destruction
  Factors affecting soil nutrients
  Factors affecting nutrient quality of vegetation
  Factors that interrupt energy flow or otherwise alter resource relationships

Community and Ecosystem Characteristics
Intra-specific competition stress
Inter-specific competition stress
Trophic relations
Species diversity and numbers/evenness
Food web diversity
Community structure
Primary/secondary production rates
Guild structure biomass
Nutrient transfer/cycling

Adaptation and Resistance
Induced detoxication mechanisms
Altered rates of uptake and/or excretion
Sequestering
Behavioral adaptation

Sensitivity Characteristics
Temperature tolerance
Depth tolerance
Salinity tolerance

Source: Conover et al. 1985, Stakhiv 1988.

When quantitative risk estimates are available and HI results indicate a significant potential for risk, conclusions from biological field studies and bioassays can be used as confirmatory weight-ofevidence to support risk conclusions and interpretation. Some additional abiotic sampling and analysis may also be needed so that the biotic data collected can he related to the chemical and physical habitat currently affecting the biota. The fate and transport of chemicals may be modeled in Tier II if needed to supplement the chemical analysis of physical media.

If there are indications that a NBDA action is being contemplated by the resource trustees for the site, it may be expedient to employ field collection efforts that satisfy both EEA Tier II data requirements and NRDA data collection requirements. For example, if baseline biotic data are to be collected from reference areas, they can be collected using methods that follow NRDA requirements for baseline determinations (43 CFR, Subtitle A, Part 11).

Following are brief descriptions of the focused field and laboratory studies appropriate within Tier II:

5.2.1 Field Studies

. Quantitative (semiquantitative) descriptive sampling in contaminated and reference areas to confirm the identity and quantity of potentially exposed biota or to measure other ecological attributes such as biological diversity (Noss 1990, Debinski and Brussard 1992) (Table 54). For example, data on vegetation community composition, structure, and diversity can be collected using semiquantitative methods such as

releve analysis and Braun-Blanquet rating methods (Mueller-Dombois and Ellenberg 1974).

- Tissue sampling of key receptor species or their dietary or prey items to document exposure. Tissue residue studies are used to provide site-specific estimates of exposure to higher trophic level organisms and to relate tissue residue levels to concentrations in abiotic environmental media. Knowledge of the physiology and biochemistry of the species to be sampled for residue analysis is important Species vary in their ability to metabolize various contaminants (e.g., fish can metabolize PAHs).

- One-time collection of exposure point media (e.g., surface water, sediment) for use in short-term (acute) laboratory bioassays.

- In situ acute bioassays, possibly using exposure point surface water and upstream water for dilution, to determine the LC_{50} contaminant concentration.

- One-time confutation surveys of Federal- or state-protected species to confirm their presence or document their potential presence (or presence of suitable habitat) and potential exposure to suspected COECs. This is in keeping with the NCP directive to "assess threats to sensitive habitats and critical habitats of species protected under the ESA" [NCP 300.43(e0(2)(i)(G)].

- If needed, one-time collection of exposure point abiotic media (e.g., soils, sediment, surface water) for additional chemical analysis to supplement existing chemical data.

- If needed, one-time collection of physical media from reference areas.

5.2.2 Laboratory Studies

- Laboratory analysis of biological samples (e.g., periphyton, benthic invertebrates, plants). as needed for taxonomy.

- Chemical analysis of collected tissue samples for COECs that are known or suspected of bioaccumulating or biomagnifying.

- Acute bioassays using onsite exposure media to determine LC_{50}s or LD_{50}s.

- Additional chemical analysis of exposure point media for specific species of COECs (e.g., chromium [+6] instead of total chromium) or selected COECs at detection levels lower than RTVs for the selected ecological receptors.

- If needed, chemical analysis of physical media collected from reference areas.

5.3 Data Collection and Analysis

Data collection from both field and laboratory studies and data analysis should be conducted in accordance with the Tier II work plan and USACE (1995b) Technical Project Planning guidance. The work plan should provide guidance from the USACE (1995b) Technical Project Planning document. At a minimum, the work plan should provide data collection objectives appropriate for Tier II, details of the proposed field studies methods, laboratory analytical methods with quantitation limits described, data quality review methodology, and plans for data presentation and integration with existing data, including data collected in Tier I.

5.4 Revision of the Tier I Era

Following the collection and compilation of biological/toxicological data from field samples and laboratory analyses, the Tier I ERA should be revised to incorporate the information and results provided by the Tier II effort. This additional information can be used to provide further quantification of ecological risk assessment and to improve risk interpretation through additional weight-of-evidence. Overall, the additional information provided through Tier II investigations should reduce the level of uncertainty associated with the baseline ERA.